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Report No. 8926-085

Materials - Alloy Steel - Ultra-High Strength
H-11 Hot Work Die Steel - Vascojet 1000
(Vanadium Alloy Steel Co.)

Rivet Shear Strength and Corrosion Resistance

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Abstract

Annealed Vascojet 1000 steel (Vanadium Alloy Steel Co., Latrobe, Penna.) rivets were cold headed from 1/8 and 1/4 inch diameter rivet wire and then heat treated. The heat treatment consisted of 1800°F for 30 minutes, air cool, 1150°F for 1-1/2 hours, air cool, 1150°F for 1-1/2 hours, air cool. The ultimate tensile strength after heat treatment of the 1/8 and 1/4 inch diameter wire was 200.7 and 191.4 ksi, respectively. Tandem protruding head rivets spaced at 4 rivet diameters, held to 2 rivet diameter minimum edge distance, and driven to head diameters about 1.5 times shank diameters were driven into 0.125 inch thick clad 7075-T6 aluminum alloy sheet lap shear joints and tested. In these tests the 1/8 inch diameter rivets yielded (0.005 inch offset) at 1638 pounds and failed at 1765 pounds with an ultimate strength of 136.2 ksi, and the 1/4 inch diameter rivets yielded (0.00625 inch offset) at 5767 pounds and failed at 6275 pounds with an ultimate strength of 121 ksi. Salt spray corrosion tests with riveted joints indicated that corrosion damage to clad 7075-T6 sheet is accelerated by the presence of unprotected Vascojet 1000 steel rivets.

Reference: Stier, H. H., Bergstedt, P. W., Turner, H.C.,
"Mechanical & Corrosion Properties of Vascojet
1000 Rivets," General Dynamics/Convair Report
MF 58-238, San Diego, California, 2 February
1959. (Reference attached.)

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SAN DIEGO

STRUCTURES & MATERIALS LABORATORIES

REPORT MP 58-238

DATE 2 February 1959

MODEL REA 7038

TITLE

REPORT NO. MP 58-238

MECHANICAL & CORROSION PROPERTIES OF VASCOJET 1000 RIVETS

MODEL: REA 7038

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OBJECT:

To determine (a) the strength and driving characteristics, and (b) the corrosive effect of VASCOJET 1000* rivets in 7075-T6 aluminum alloy sheet.

CONCLUSION:

1. The shear strength of double-tempered VASCOJET 1000* wire increases parabolically with increasing hardness of the wire in the range from 42-51 Rockwell C (when tested at room temperature in a double-shear fixture).
2. Lapped joints in bare 7075-T6 sheet fastened by double-tempered VASCOJET 1000 rivets of 42-44 Rc hardness with protruding flat heads have these strengths (when tested at room temperature):

	1/8" diam. rivets in .125" thk. sheet	1/4" diam. rivets in .250" thk. sheet
--	--	--

Ultimate shear, psi	136,200	121,000
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3. VASCOJET 1000 wire double-tempered to 42-44 Rc hardness has an ultimate tensile strength of 191,000 - 201,000 psi.
4. The force required to squeeze a $.337 \pm .005$ in. diameter head on a .250 in. diameter VASCOJET 1000 rivet varies with the hardness.

	Rivets of 44 Rc hardness	Rivets of 50 Rc hardness
--	-----------------------------	-----------------------------

Rivet-driving force, pounds	23,400	28,400
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5. Rivet heads squeezed to $.337 \pm .005$ in. diameter on .250 in. diameter VASCOJET 1000 rivets of 42-51 Rockwell C hardness show no rejectable cracks.
6. Corrosion in clad 7075-T6 sheet is accelerated by the bare VASCOJET 1000 rivets.

TEST SPECIMENS:

Rivets were cold-headed from VASCOJET 1000 wire in the annealed condition and then heat-treated as follows:

- a. Austenitize at 1850°F. in a neutral atmosphere for 30 minutes, air cool.

* VASCOJET 1000 is Vanadium-Alloy Steel Company's designation for an AISI-Hill steel.

TEST SPECIMENS: (Continued)

b. Temper at 1150°F. in air for 1 1/2 hours, air cool.

c. Temper again at 1150°F. in air for 1 1/2 hours, air cool.

The 1/8 in. diameter rivets were squeezed with a Chicago Pneumatic compression riveter; the 1/4 in. diameter rivets were gunned with a G-8 pneumatic rivet gun. Rivet shanks protruded 1.12 diameters before driving in the sheet combinations of this test.

The shear specimens were of the single lap-joint type with two tandem rivets spaced along the longitudinal center-line of the joint as shown in the sketch in Table I. Corrosion specimens had three driven rivets spaced at one inch along the longitudinal center-line of .125" x 1 1/2" x 10" clad 7075-T6 sheet.

TEST PROCEDURE:

The riveted lap-joints were pulled in a 60,000 pound Timius-Olsen tensile machine at a maximum loading rate of 1000 pounds/min. for 1/8 in. diameter rivets and 4000 pounds/min. for 1/4 in. diameter rivets. An S-1 extensometer was used to measure the yield strength of the joint as described in Report MP 58-262. The yield load was taken at a permanent joint set of .005 in. for 1/8 in. diameter rivets and .00625 in. for 1/4 in. diameter rivets.

Tensile specimens of 15 in. lengths of wire were inserted into 1/8 in. or 1/4 in. I.D. jaws and pulled at .001 in./in./min. to determine the tensile ultimate of the wire. The I.D. of the jaws was smooth to prevent notching of the wire. An abrasive coating on the ends of the wire was needed to overcome slipping in the jaws.

Shear tests of tempered wire were performed in a double-shear fixture. Before shearing the wire, the hardness was taken along the diameter of a polished and etched cross-section through the wire. Vickers hardnesses were measured with a diamond pyramid indenter in a Tukon tester with a 10 Kgm. load. The specimen was broken out of its lucite mount before measuring the Rockwell C hardness of the cross-section.

The corrosion specimens were wiped with alcohol and placed in a salt spray cabinet for observation. The salt spray was operated in accordance with Federal Test Method Standard 151, Method 811.

RESULTS & DISCUSSION:

The heat treatment for VASCOJET 1000 rivets for this test was selected on the basis of the double-shear tests of wire tempered to different hardnesses. (See Figure 1). A shear strength of 139,000 psi. was achieved by tempering to about 44 Rc hardness. Two different double-tempering treatments which produced a 44 Rc hardness are given below:

a. 1100°F., 2 1/2 hours, AC + 1100°F., 2 1/2 hours, AC.

ANALYSIS

PREPARED BY Stier

CHECKED BY Bergstedt/Turner/Sutherland

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RESULTS & DISCUSSION: (Continued)

b. 1150°F., 1 1/2 hours, AC + 1150°F., 1 1/2 hours, AC.

NOTE: An austenitizing treatment at 1850°F. in a neutral atmosphere for 30 minutes, followed by air cooling, put the material in a fully hardened condition before double-tempering.

The 139,000 psi ultimate shear strength was selected so that failure would occur in the rivets before the bearing strength of the bare 7075-T6 sheet was exceeded.

No sheet bearing failures occurred in tests of lapped joints in 7075-T6 sheet incorporating VASCOJET 1000 rivets of 42-44 R_C hardness. (See Table I.)

The ultimate tensile strength of VASCOJET 1000 wire of 42-44 R_C hardness is given in Table II.

The load required to squeeze the protruding heads of the 1/4 in. diameter VASCOJET 1000 rivets to .337 ± .005 in. diameter is given in Table III. Driven heads showed very minute surface cracks (not rejectable according to MPS-46.05D).

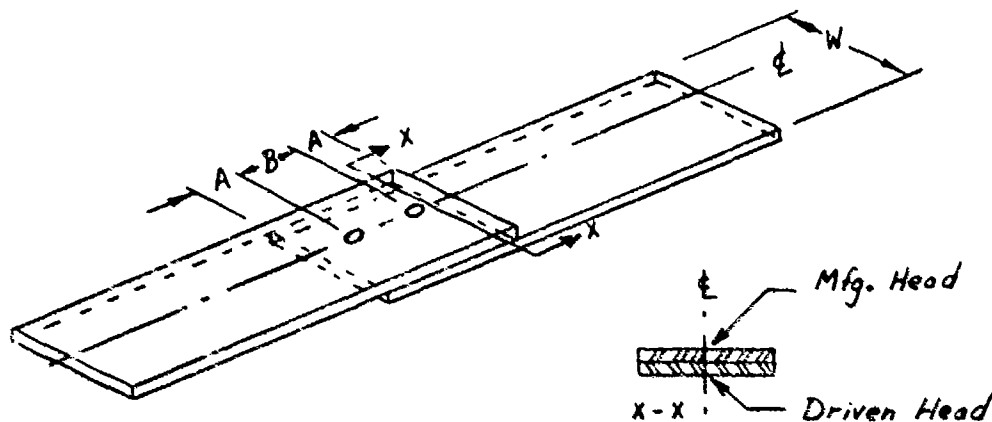
The corrosion specimen incorporating VASCOJET 1000 rivets in clad 7075-T6 sheet was severely attacked after 250 hours in the salt spray cabinet. The cladding was completely removed in areas up to one inch in diameter near each rivet head. Rivet heads showed no corrosion. Coatings of diffused or plated metals on the VASCOJET 1000 rivets may be applied for protection against corrosion.¹

1. "Steels and Protective Treatments for Use up to 1000°F.," H. A. Saele and W. H. Sharp, SAE Transactions, Volume 64, 1956, pp. 74-75.

NOTE: The data for this report have been recorded in the Materials and Processes Laboratory Notebook No. 3011.

TABLE I. RESULTS OF SHEAR TESTS OF RIVETED LAP-JOINTS INCORPORATING PROTRUDING HEAD RIVETS OF TEMPERED^(a) VASCOJET 1000^(b) STEEL IN 7075-T6 SHEET (bare).

Identif.	Rivet Driving Method	Meas'd. Hole Diam., in.	Driven Head Diam., in.	Sheet Thk., in.	YIELD LOAD, #/rivet	ULT. LOAD, #/rivet	ULT. STRENGTH, PSI. (c)	TYPE OF FAILURE (d)
VJ-1	G-8 gun	.257-.258	.347-.362	.250	5637	5950	114,800	1 & 2
VJ-2	"	.257	.356-.369	"	5650	6300	121,400	2
VJ-3	"	.257-.258	.353-.359	"	6013	6575	126,800	1 & 2
				Avg.	5767	6275	121,000	
VJ-4	Squeeze	.1285	.180	.125	1595	1720	132,600	2
VJ-5	"	"	.176-.181	"	1605	1735	134,000	2
VJ-6	"	"	.177-.178	"	1715	1840	142,000	2
				Avg.	1638	1765	136,200	



SPECIMEN DIMENSIONS:				
Sheet Thk., in.	Rivet Diam., in.	A in.	B in.	W in.
.125	1/8	1/2	3/4	1 1/2
.250	1/4	5/8	1	1 1/2

- (a) Rivets were tempered to a Rockwell hardness of 42 - 44 R_c before driving (1850° F., 30 min., AC + 1150° F., 1 1/2 hr., AC + 1150° F., 1 1/2 hr., AC).
- (b) Vanadium-Alloys Steel Company's designation for an AISI-H11 steel.
- (c) Based on measured hole diameter.
- (d) See FAILURE NOTES below:

1. Mfg. heads snapped off.
2. Rivets sheared in the shank along sheet interface.

TABLE II. RESULTS OF TENSILE TESTS OF TEMPERED (a) VASCOJET 1000 (b)
 RIVET WIRE

Wire Diam., inch	Area, in. ²	Length, inch	ULT. LOAD, pounds	ULT. TENSILE STRENGTH, PSI.
.1258	.012425	16	2520	202,898
"	"	"	2470	198,872
"	"	"	2490	200,483
		Avg.	<u>2493</u>	<u>200,751</u>
.2505	.04926	16	9370	190,215
.2503	.04918	"	9570	194,591
"	"	"	9320	189,507
		Avg.	<u>9420</u>	<u>191,438</u>

(a) Wire tempered to a Rockwell hardness of 42 - 44 R_C (1850° F., 30 min., AC + 1150° F., 1 1/2 hr., AC + 1150° F., 1 1/2 hr., AC).

(b) Vanadium-Alloy Steel Company's designation for an AISI-H11 steel.

TABLE III. RESULTS OF RIVET-DRIVING TESTS OF TEMPERED (c) VASCOJET 1000 (a)
RIVETS IN 7075-T6 SHEET (bare)

Rivet Diam., in.	Hole Diam., in.	Driven Head Diam., in.	Sheet Thk., in.	Rivet Set	Rivet Hardness, R _C	LOAD REQUIRED TO SQUEEZE RIVET, pounds	Remarks
.250	.257	.3356	.125	Flat	42-43	20,400	(b)
"	"	.3392	"	"	"	21,600	"
"	"	.3408	"	"	"	21,800	"
Avg.						21,800	
.250	.257	.3349	.125	Flat	43-44	23,600	(b)
"	"	.3409	"	"	"	21,600	"
"	"	.3415	"	"	"	25,000	"
Avg.						23,400	
.250	.257	.3327	.125	Flat	44-45	22,300	(b)
"	"	.3356	"	"	"	22,800	"
"	"	.3366	"	"	"	23,200	"
Avg.						22,800	
.250	.257	.3350	.125	Flat	50-51	28,300	(b)
"	"	.3366	"	"	"	27,800	"
"	"	.3416	"	"	"	29,150	"
Avg.						28,400	

(a) Vanadium-Alloys Steel Company's designation for an AISI-H11 steel.

(b) Driven heads showed very minute surface cracks about .010" long and a few mils deep.

(c) Tempered to the hardnesses indicated in column 6 before driving.

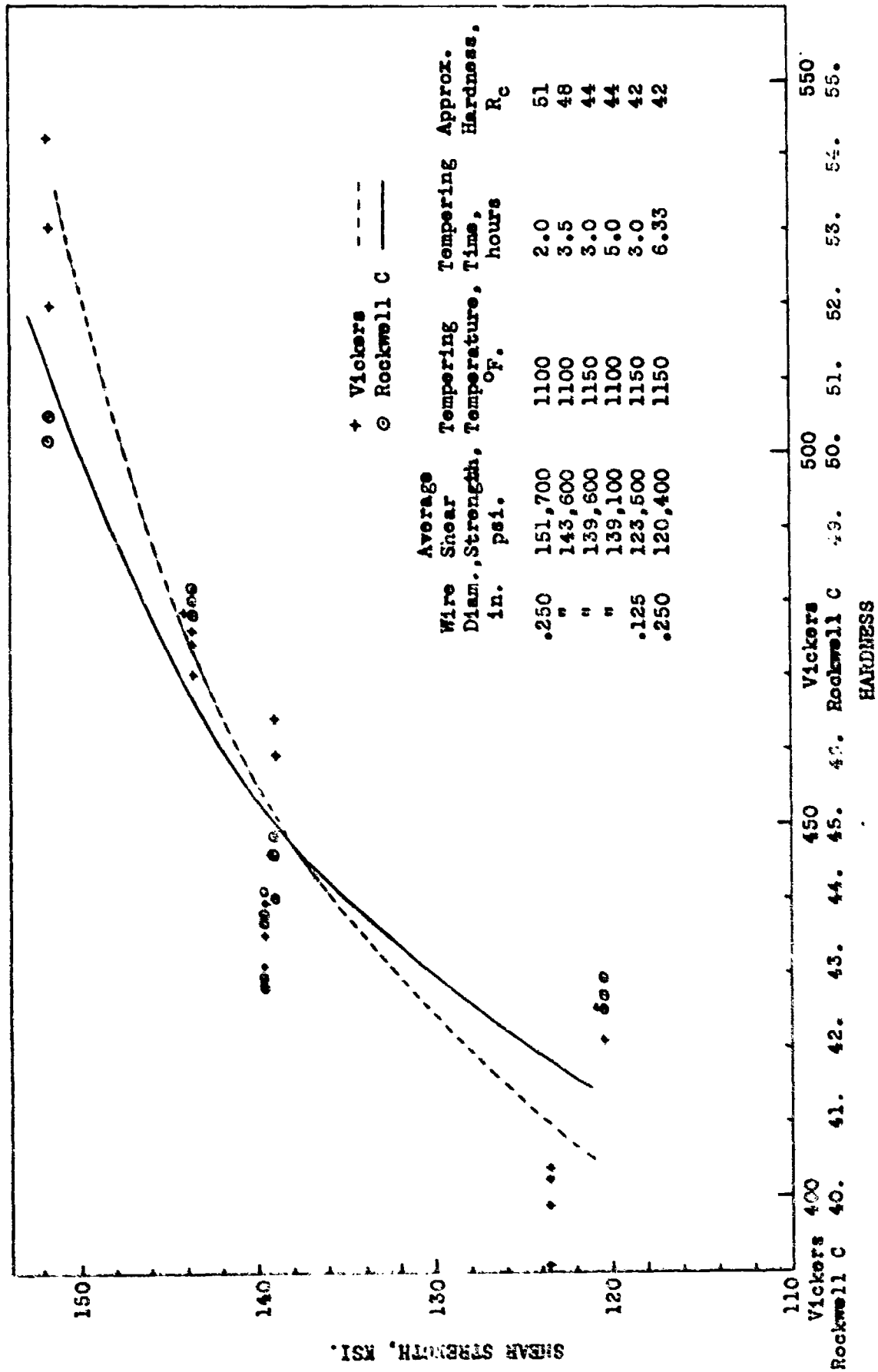


FIGURE 1. Shear Strength of VASCOJET 1000® Wire Tempered to Various Hardnesses

- Vanadium-Alloys Steel Company's designation for an AISI-H11 steel.
- Composition: 0.40 % C, 5.0 % Cr, 1.30 % Mo, 0.50 % V.